

A GEARBOX VIBRATION - FACT OR FICTION

Brian C. Howes

Beta Machinery Analysis Ltd. Calgary AB, Canada, T3C 0J7

ABSTRACT

A case study of a gearbox. Late last fall, routine monitoring of a gearbox showed an increase in overall vibration levels, which was not apparent in the spectra. If the gearbox failed during the winter, the process plant would not have been able to start up again until spring. Plant engineers called us in to determine whether the gearbox would run through the winter. The investigation uncovered problems with the way the routine monitoring was done. As well, vibration was present in the spectra that seemed to be unrelated to gearmesh frequency. Was there a problem or not?

1. INTRODUCTION

This case history started with a phone call, requesting assistance to check the condition of a gearbox in a fertilizer plant. Overall vibrations collected with a periodic predictive maintenance program had shown a sudden and dramatic increase in vibration levels on the gearbox.

There was a heightened sense of awareness of gearboxes amongst the people in the plant because a similar gearbox had failed without warning a few months earlier. Furthermore, since it was late fall when we received the phone call, a plant shutdown to repair this gearbox would still be acceptable, though obviously undesirable. A full plant turnaround was planned for the spring. The concern was that an unplanned shutdown in the cold of winter would probably result in startup problems that might even prevent restarting the plant till spring.

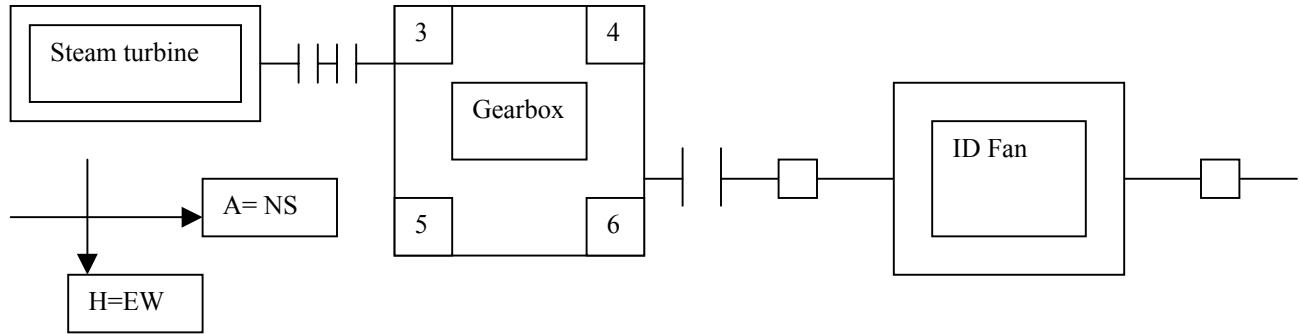
Despite the critical nature of the problem, there were limits placed on what we were able to do as part of our testing. We were not allowed to change the speed of the fan, let alone shut the fan down. There was no once-per-turn marker available on the system.

Our report (Reference 1) indicated that the gearbox would be acceptable till the next year, but that there were ways to improve the periodic vibration system being used in the plant.

2. SYSTEM DESCRIPTION

The layout of the system and a description of the gearbox is shown below. The steam turbine and ID fan are not described.

Layout of the machine



Gearbox

Horsepower 1113
Service Factor 2.44
SN 32671
Max. Input speed 5672 RPM
Max. Output speed 1167 RPM
Pinion Teeth 43
Bull gear Teeth 209
Max. gear-mesh frequency 4064Hz
Gear Ratio 4.860465

The following photographs show some views of the gearbox with testpoint locations indicated.



Picture 1: High speed side of the box, Test Points 3 and 4: (Turbine to the right)



Picture 2: View of Test Point 5 with accelerometer mounted with stud on nut glued to box in Horizontal orientation. The oil pump is on the turbine side of the low speed shaft.



Picture 3: Optical pickup on the low speed shaft. Once per turn mark was put on the shaft while it was running.



Picture 4: Gearbox base on the south side.

3. ANALYSIS OF THE GEARBOX VIBRATIONS

We collected vibration data from the gearbox. Time domain, frequency domain, and averaged data (time averaging and frequency averaging) were collected.

Figure 1 is representative of the data. It was collected in the horizontal direction, near the bearing on the output side of the low speed shaft. The accelerometer was mounted on a nut, which had been glued to the gearbox.

Based on the speed of the output shaft and the number of gear teeth given to us, the gearmesh frequency was 3494 Hz. Note in the spectrum plot in Figure 1, that there is a peak in the acceleration spectrum approximately at this frequency (3504 Hz). However, the major peak in the spectrum is at 4828 Hz, which is 1.38 times gearmesh frequency.

Close inspection did not disclose significant amplitudes at harmonics of gearmesh, or sidebands. The time domain data did not show any spikes. Generally, the gearbox looked to be in good condition based on normal dynamic indicators, except for the unusual peak at 4828 Hz.

Further analysis of the 4828 Hz peak could not be done because of restrictions on changing speed. However, it can be seen that there are many small peaks around the main 4828 Hz peak. This energy is consistent with the idea that there is a mechanical natural frequency (MNF) of the gearbox case that is at or near 4800 Hz. Changing the speed of the unit would have permitted us to test this theory. Experience has shown, however, that frequently there are MNFs which are excited in a gearbox. While it is not a particularly good sign, it is not

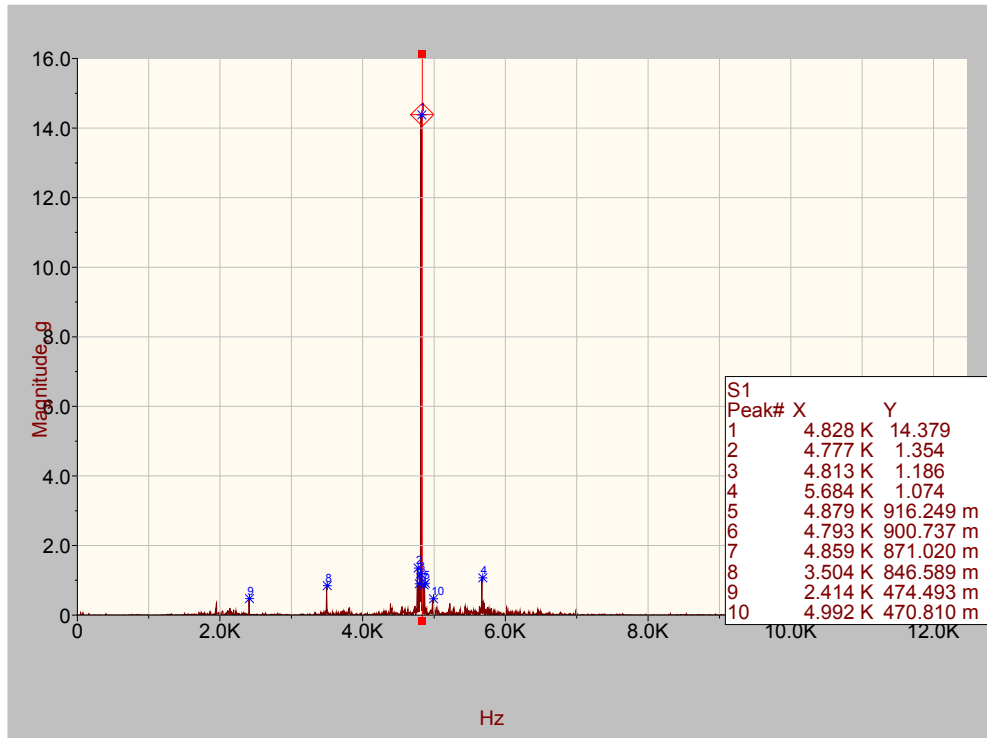
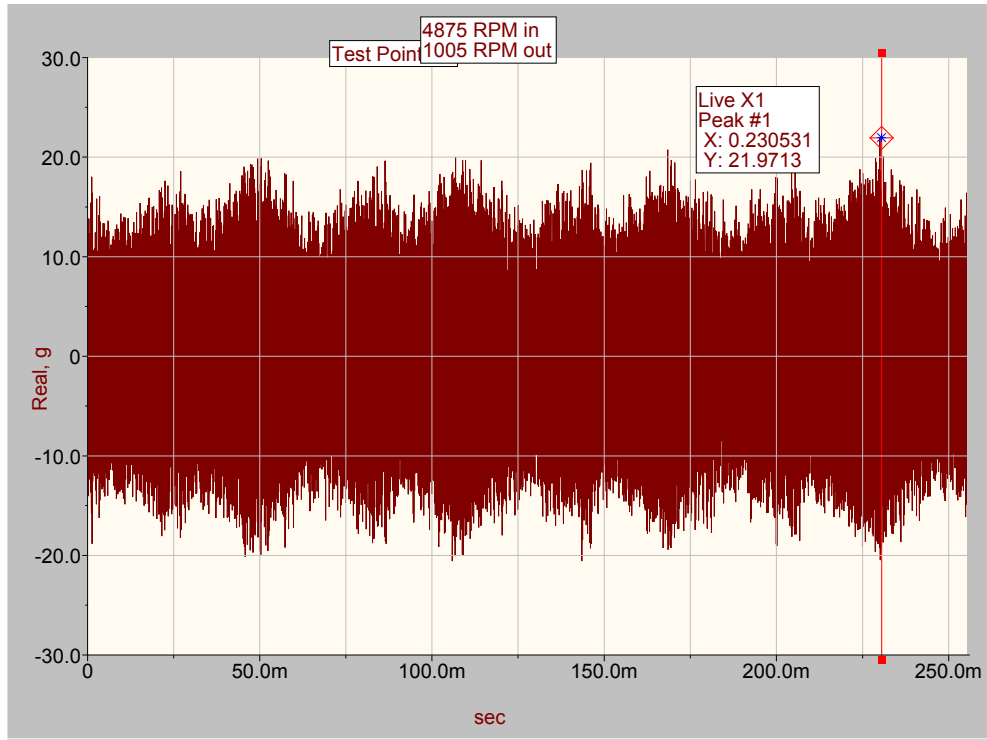


Figure 1: Test point 6H Acceleration Data

necessarily an indication of a serious problem with the gearbox in the absence of harmonics and sidebands. It is more likely a sign that the gearbox manufacturing tolerances were looser than what can be achieved (but at what cost?).

Vibrations were collected in a similar manner at Test Points 3, 4 and 5 in the horizontal direction. Refer to Pictures 1 and 2 for details of the test point locations.

Refer to Picture 3 for details of the once-per-turn setup. As noted, the mark was put on the shaft without shutting down the unit.

Picture 4 shows the feet of the gearbox on the south side. This is shown in connection with the soft foot check that was done. We checked for the effect of a soft foot on the vibrations by loosening and tightening one foot at a time. The change in vibrations was noted for each of the four feet. Foot 5 showed the largest change in vibrations. The overall vibrations (from the time domain data) decreased by 6%. The amplitude of the vibration at 4828 Hz decreased by 22% when the anchor bolt was loosened.

4. CONCLUSIONS AND RECOMMENDATIONS FROM THE ANALYSIS

We concluded that the gearbox was in good enough condition to run till the planned turnaround next spring. We did, however, recommend doing a few additional checks to ensure that this conclusion was correct. We recommended checking the oil in the gearbox for wear metals. We also recommended checking the oil filters for any sign of metal.

At the time of writing this paper, the gearbox has run successfully over the winter. The plant is now in turnaround, as planned.

5. DISCUSSION OF THE PREDICTIVE MAINTENANCE DATA

The periodic collection of vibration (and other) data is generally a good concept. In order for the process to give maximum benefit, the planning and implementation of the system should be carefully considered, and reviewed from time to time.

In this case, we were not able to determine how the vibrations data had been collected. Was the method the same before and after the increase in overall vibrations? It could have been collected with a stinger on the accelerometer (hand held), and then a change made to a magnet. Alternatively, a magnet may have been used, but the condition of the magnet may have changed. Similarly, we were unable to determine exactly where the test points were that had been used.

We did observe that all of the spectral information was taken with a maximum frequency (Fmax) of 2500 Hz. Unfortunately, this Fmax is less than gear mesh frequency, let alone the first or second harmonic of gear mesh.

(Note: There is a common tendency to incorrectly use the term “harmonic”. A harmonic requires a fundamental frequency to be present. The first harmonic of the fundamental frequency is two times the fundamental frequency.)

Nonetheless, the overall vibrations did increase. Why? Although we were not sure of the frequency range included in the data used to calculate the overall amplitude, it could have been up to the Fmax setting for the spectra, or up to the maximum frequency of the instrument. As a minimum, the energy measured by the data collector had increased in the range of frequencies below 2500 Hz.

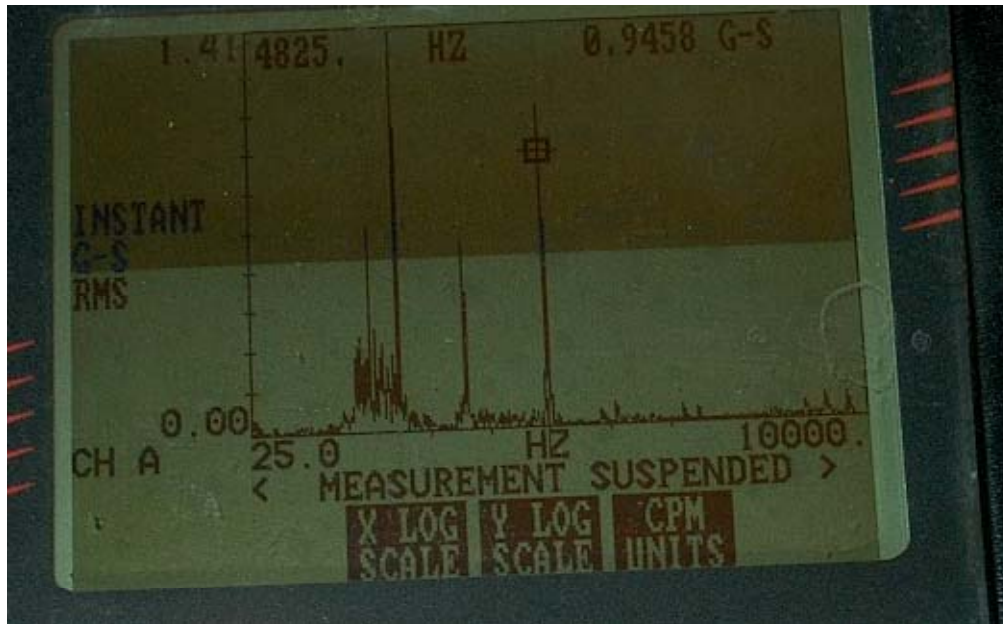
Based on experience, we were suspicious of the use of either handheld or magnetically mounted accelerometers for collection of data above 1000 Hz. To test the effect of a magnetic mount versus a stud mount, we did a test. The results of the test are shown in two photographs of the screen of the instrument (Pictures 5 and 6).

Observe the dramatic change in vibration energy below the gearmesh frequency peak at 3500 Hz. Stud mounting increased the amplitudes of the peaks at gearmesh and 4820 Hz. The good news is that all of the peaks are present, albeit at different amplitudes, in both spectra.

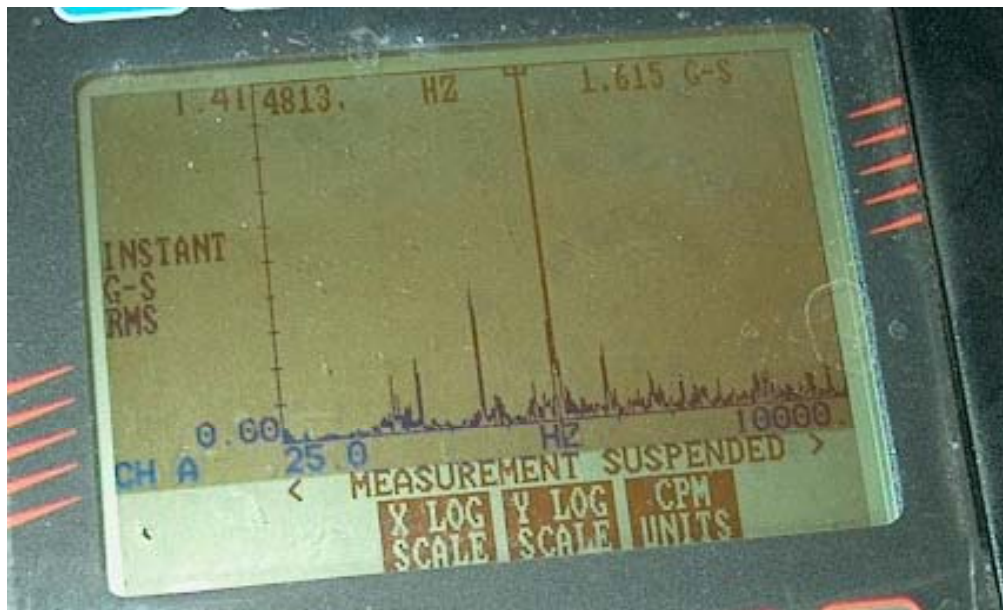
The biggest reason for not using a magnet to mount an accelerometer for high frequency measurements is the desire to collect data repeatably. The frequency response of the accelerometer is influenced by the connection of the magnet to the gearbox. Changes in the thickness of the paint will change the frequency response and produce an apparent change in the condition of a gearbox. Dirt under the magnet will do the same thing. Poorly mounting the magnet (not “wiggling” the magnet to ensure the magnet is solidly mounted) will do the same.

But one of the most significant sources of lack of repeatability is a loss of magnetic strength in the magnet. This comes with time and use (or misuse) of the magnet. Instructions with magnets tell the user to slide the keeper (usually a steel washer) on and off the magnet. It is a natural tendency to let the keeper impact the magnet. This is bad. It tends to realign the magnetic particles in a random order, thus causing a loss of magnetic pull. In this case, the magnet that came with the collector was not particularly strong and it seemed to be even weaker than experience suggested it should have been. Changes in the magnet may have been the reason for the increase in overall vibrations.

Lest it be said that this case history suggests that periodic vibration collection is a bad thing, it does seem that it is better to have an occasional false alarm than to miss a real problem.



Picture 5: Vibrations at 6H with magnet mount



Picture 6: Vibrations at 6H stud mounted

6. CONCLUSIONS

Vibration measurements can tell us about the condition of a gearbox, if properly done. Other physical parameters besides vibrations can be helpful.

Trending of data should be helpful, but only if the data being trended is collected consistently.

Methods of mounting of transducers, such as accelerometers used for measuring high frequency data, are important. Repeatability of data collection is the most important consideration in choosing a mounting method.

Periodic data collection programs should be reviewed by an unbiased third party. Such a review could have benefit at the start of a program to ensure that the test points and frequency ranges are correct. After the program has been active for a few years, benefit might be derived from a review of the cost-effectiveness of the program.

7. REFERENCES

- (1) Gearbox Analysis, dated October 25, 2001, by Brian Howes, Beta Machinery Analysis Ltd., Reference number 103363

8. BIOGRAPHY

Brian Howes is Chief Engineer for Beta Machinery Analysis Ltd., Calgary. His previous experience includes: research and development in the area of pulsations and vibrations of reciprocating compressor piping systems, 30 years of troubleshooting problems in many countries with a wide range of equipment including turbines, centrifugal and plunger pumps, centrifugal, screw and reciprocating compressors, pulp refiners, paper machines, ball mills, furnaces and piping systems. He has a Master of Science in Solid Mechanics from the University of Calgary, and is a past member of the Board of Directors of the Canadian Machinery Vibration Association (CMVA).